XIII. *On some Properties of Light. By* David Brewster, *LL.D. F.R.S. Edin. In a Letter to Sir* H. Davy, *LL.D. F.R.S.*

Read January 28, 1813.

Dear Sir,

Having been for some time engaged in a series of experiments on the phenomena of light arising from its transmission through diaphanous bodies, I have taken the liberty of communicating to you, for the information of the Royal Society, a short and general account of the results of my enquiries. In the narrow compass of a letter, it would be impracticable to include the various details of these experiments; the particular methods of observation that were employed; or the numerical results which I have obtained for the refractive and dispersive powers of nearly two hundred substances. As these will form part of a separate work, in which I am now engaged, I shall confine myself at present to some of those results which appear to be most interesting, either from their novelty or importance.

1. *On a new Property of refracted Light.*

As you are already well acquainted with the optical properties of doubly refracting media, and the analogous property of reflected light discovered by Malus, it will be unnecessary to take any notice of these phenomena. After repeating the experiments of Malus, and measuring several of the angles

of incidence at which this property was communicated to light by reflection from different substances, I made a variety of experiments, with the view of discovering if a similar character could be impressed upon light by its *transmission* through bodies, either wholly or imperfectly transparent. All these experiments afforded no new result, and every hope of discovering such a property was extinguished, when my attention was directed to a singular appearance of colour in a thin plate of agate. This plate, bounded by parallel faces, is about the fifteenth of an inch thick, and is cut in a plane perpendicular to the laminæ of which it is composed. The agate is very transparent, and gives a distinct image of any luminous object; but on each side of this image is one highly coloured, forming with it an angle of several degrees, and so deeply affected with colour that no prism of agate, with the largest refracting angle, could produce an equivalent dispersion. Upon examining this coloured image with a prism of Iceland spar, I was astonished to find that it had acquired the same property as if it had been transmitted through a doubly refracting crystal, and upon turning the Iceland spar about its axis, the images alternately vanished at every quarter of a revolution. My attention was now directed to the common colourless image formed by pencils transmitted perpendicularly through the agate; and by viewing it through a prism of Iceland spar, it exhibited all the characters of one of the pencils produced by double refraction, the images alternately vanishing in every quadrant of their circular motion.

When the image of a taper reflected from water at an angle of 52° 45′, so as to acquire the property discovered by MALUS, is viewed through the plate of agate, so as to have its laminæ

parallel to the plane of reflection, it appears perfectly distinct; but when the agate is turned round, so that its laminæ are perpendicular to the plane of reflection, the light which forms the image of the taper *suffers total reflection, and not one ray of it penetrates the agate.*

If a ray of light incident upon one plate of agate is received after transmission upon another plate of the same substance, having its laminæ parallel to those of the former, the light will find an easy passage through the second plate; but if the second plate has its laminæ perpendicular to those of the first, the light will be wholly reflected, and the luminous object will cease to be visible.

Owing probably to a cause which will afterwards be noticed, there is a faint nebulous light unconnected with the image, though always accompanying it, and lying in a direction parallel to the laminæ. This light never vanishes along with the images, though it is evidently affected by the different changes which they undergo; and in one of the specimens of agate, it is distinctly incurvated, having the same radius of curvature with the adjacent laminæ. This character of the nebulous light I consider as an important fact, which may be the means of conducting us to a satisfactory theory, and I am at present engaged in examining it with particular care.

This remarkable property of the agate I have found also in the kindred substances of cornelian and chalcedony, and it is exhibited in its full effect even when these bodies are formed into prisms, and when the incident rays fall with any angle of obliquity. In one specimen of agate, which has no veins to indicate the direction in which it was cut, the images did not vanish as before; and in another specimen of the same

character the images suffered only an alternate diminution of brightness, in the same manner as a pencil of light receives only a partial modification when reflected from water at a greater or a less angle than 52° 45′.

The different experiments which have now been mentioned were repeated, with the most satisfactory results, by Mr. Playfair, Dr. Hope, and Mr. John Davy.

Although the preceding results are by no means ripe for generalization, I cannot omit the present opportunity of hazarding a few conjectures respecting the cause of this singular property of the agate.

May not the structure of this mineral be in a state of approach to that particular kind of crystallization which affords double images? and may not the nebulous light be an imperfect image arising from that imperfection of structure? When one of the images vanishes, the nebulous light which encircled it is then a maximum, and it gradually diminishes during the re-appearance of the image. When the image which had disappeared recovers its full lustre, the surrounding nebulosity is very small, and this remaining light is, in all probability, no portion of the unformed image, but merely a few scattered rays arising from the imperfect transparency of the mineral.

By forming the agate into a prism, the nebulous light should be separated from the image which it encloses, in proportion to the angle contained by the refracting planes; but owing, perhaps, to the smallness of its double refraction, if it has such a property, I have not observed any separation of this kind.

The incurvated form of the nebulous light corresponding with the curvature of the laminæ, seems to connect it with the

laminated structure of the agate, and to indicate that the phenomena of double refraction are produced by an alternation of laminæ of two separate refractive and dispersive powers. In Iceland spar, one set of the laminæ may be formed by a combination of oxygen and calcium, while the other set is formed by a combination of oxygen and carbon. In chromate of lead, the chromium and oxygen may give one image, while the oxygen and lead give another. In like manner the carbonate of lead, the carbonate of strontites, jargon, and other crystals may give double images, in virtue of similar binary combinations. Of the simple inflammable bodies, sulphur is the only one which has the property of double refraction, but it will probably be found that it holds a metal or some other ingredient in its composition, which chemists have not been able to discover.

If the explanation which has now been given of the polarising power of the agate should be confirmed by future experiments, this property will be considered as a case, though a very curious one, of double refraction; but if these conjectures should be overturned, the phenomena which we have described must be ranked among the most singular appearances in the wide range of optical science.

2. *On the double Refraction of Chromate of Lead.*

In the course of my experiments on refractive powers, I discovered a double refraction in this metallic salt of such enormous magnitude, that the deviation of the extraordinary ray is more than thrice as great as that produced by Iceland spar. The ratio of the sines, for both refractions, and the other

properties of this extraordinary mineral will be noticed in the next article.

3. *On Substances with a higher refractive Power than the Diamond.*

Since the time of Sir ISAAC NEWTON, who first measured the action of the diamond upon light, its refractive power has been regarded as superior to that of every other substance; but, in the course of my researches, I have found that realgar and chromate of lead exceed the diamond in refractive power, and that this high refraction, in both these substances, is accompanied with dispersive powers greater than those of any other body. The following are the measures which I have obtained for these, and a few other substances.

Refractive Powers.

	Index of Refr.		Index of Refr.
Chromate of lead (gr. refr.) - -	2.926	Phosphorus - -	2.224
Ditto, least refraction	2.479	Sulphur, native -	2.115
Realgar - -	2.510	Cryolite - -	1.344
Diamond (according to NEWTON) - -	2.439	Ice - -	1.307

Dispersive powers or values of $\frac{dR}{R-1}$.

Chromate of lead (gr. refr.) - -	0.400	Phosphorus - -	0.128
Ditto, least refraction	0.262	Flint glass (highest)	0.052
Realgar - -	0.255	Diamond -	0.038
Oil of cassia -	0.139	Water - -	0.035
Sulphur - -	0.130	Fluor spar - -	0.022
		Cryolite - -	0.022

It appears from the first of these tables, that phosphorus

is next to diamond in refractive power, and that the three simple inflammable substances have their refractive powers in the order of their inflammability. Dr. WOLLASTON has placed phosphorus below horn and flint glass,* but I am confident that this distinguished philosopher, to whom the physical sciences are so deeply indebted, will find, upon making the experiment with prisms or lenses, that I have assigned the right place to that remarkable substance. The difference between the extreme dispersive powers in the second table is very remarkable, and the result for oil of cassia indicates in that body the existence of some ingredient, which chemical analysis has not been able to detect.

4. *On the Existence of two dispersive Powers in all doubly refracting Crystals.*

It has been long known, and it is indeed obvious, from a simple inspection of the images formed by a prism of Iceland crystal, that the one image is more coloured than the other, or that the actual *dispersion* of the one refraction is greater than the *dispersion* of the other, in the same manner as the *dispersion* of a prism of flint glass with a refracting angle of 12 degrees, is greater than the dispersion of a prism of the same glass with an angle of only 10 degrees.

Dr. WOLLASTON, who was the first person that examined the subject of dispersive powers with philosophical accuracy, makes the dispersive power of Iceland spar considerably above water, and even above diamond. Upon repeating this experiment, with the least refracted image, I found the dispersive

* Dr. WOLLASTON is satisfied that his original estimate was erroneous, and that Dr. BREWSTER's determination is very near the truth. H. D.

power, or the value of $\frac{dR}{R-1}$, to be 0.026 very considerably below water, which stands at 0.035 of the scale, and I therefore concluded that Dr. Wollaston had examined the greatest refraction, while I had examined the least, and that the vast discrepancy between our measures arose from the existence of a double dispersive power. This conclusion was confirmed by determining the dispersive power of the greatest refraction, which coincided exactly with the order assigned to it by Dr. Wollaston.

The dispersive powers, which I have obtained for other doubly refracting crystals, such as carbonate of strontites, carbonate of lead, and chromate of lead, have confirmed this result, and establish the general law, that each refraction of crystals which give double images is accompanied with a separate dispersive power. The double dispersive powers of these bodies are given in the following table.

Chromate of lead	(gr. refr.)	estimated at	0.400
Ditto	Ditto	must exceed	0.296
Ditto	(least refr.)	- -	0.262
Carbonate of lead	(gr. refr.)	-	+ 0.091
Ditto	(least refr.)	- -	0.066
Carbonate of strontites	(gr. refr.)	-	0.046
Ditto	(least refr.)	-	0.027
Calcareous spar	(gr. refr.)	- -	0.040
Ditto	(least refr.)	-	0.026

In a table of refractive powers, published by the late Mr. Cavallo, he has given, from other authors, the *dispersions*, or the *dissipations* as he calls them, of a few substances, and he has annexed a different *dispersion* to the two refractions of

Iceland crystal; but it is obvious, from a simple inspection of the table, that these are measures of the *dispersion* or *quantity of colour,* and not of the *dispersive power* of the substances. The measures in the table alluded to, with the exception of one or two, are so completely incompatible with those taken by Dr. WOLLASTON and myself, that I can scarcely believe that the experiments were ever made.

The singular property of a double dispersive power, while it seems to exclude some of the theories by which the double refraction has been explained, adds another to those numerous difficulties with which philosophy has yet to struggle, before she can reduce to a satisfactory generalization those anomalous and capricious phenomena which light exhibits in its passage through transparent bodies.

I have the honour to be,

dear Sir,

your most obedient humble servant,

DAVID BREWSTER.

Edinburgh, 23, Duke-street,
December 19, 1812.

To Sir H. Davy, LL.D. F.R.S.